# Mobile, Fast and Cost-Effective Diagnostic System for Clinical Analyses
# Simulation of Bead Movement in Magnetic Field

Sven Reitz
Fraunhofer Institute for Integrated Circuits IIS, Division Engineering of Adaptive Systems EAS, Dresden, Germany

**INTRODUCTION**: In a diagnostic system small magnetic beads of about 1µm diameter will be moved along a path in a viscose medium due to magnetic field actuators. Specific ligands on the beads will bound to specific samples. If bound, the diameter and mass of the beads rise and the bead movement is slower resulting in a shorter path in a fixed timeframe. The length of the path can be used to detect the samples or for sorting them in case of lateral deviations/curved movement. Goal of the simulation work is to understand the bead movement and derive first geometrical, magnetic, and electrical parameters of the diagnostic system.

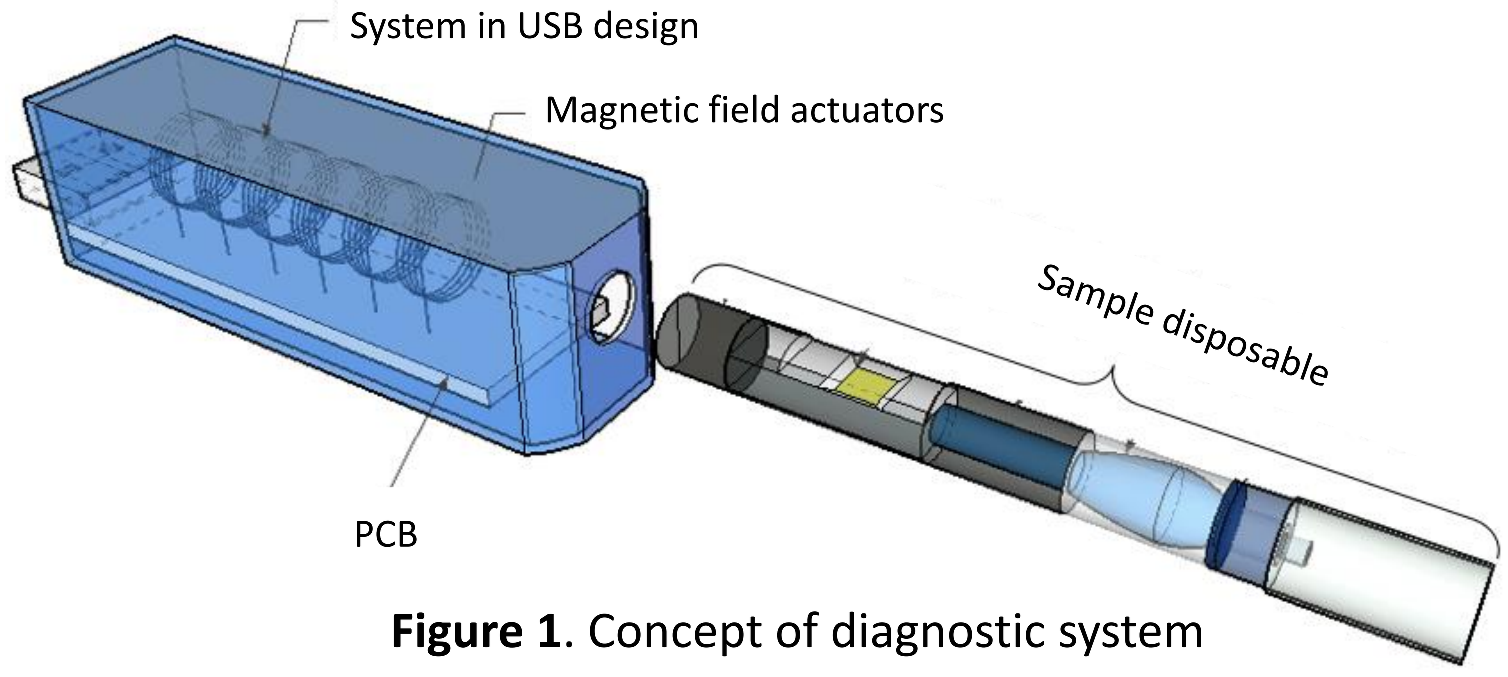


**Figure 1**. Concept of diagnostic system

**COMPUTATIONAL METHODS**: The inductors cause magnetic fields resulting in forces acting on the beads. Contrary to this, frictional forces on the interface between the viscose fluid and the beads act. Stokes's law can be used to set the frictional forces $F_d$ in relation to the velocity $v$ of a bead with radius $R$ in a medium with dynamic viscosity $\eta$:

$$F_d = 6\pi\eta R v$$

In a first model a sweep is done for a grid of radial (x) and height (z) positions of a bead to compute the magnetic forces acting on the bead in both directions and to export them to a file. In a second model the forces are used in interpolation functions Fx(x,z) and Fz(x,z) to provide them to a global ODEs/DAEs section with the Stokes's law stored in a global equations node:

| name | f(u,ut,utt,t) (m/s) |
|---|---|
| x | xt-Fx(x,z)/(6*pi*eta*r) |
| z | zt-Fz(x,z)/(6*pi*eta*r) |

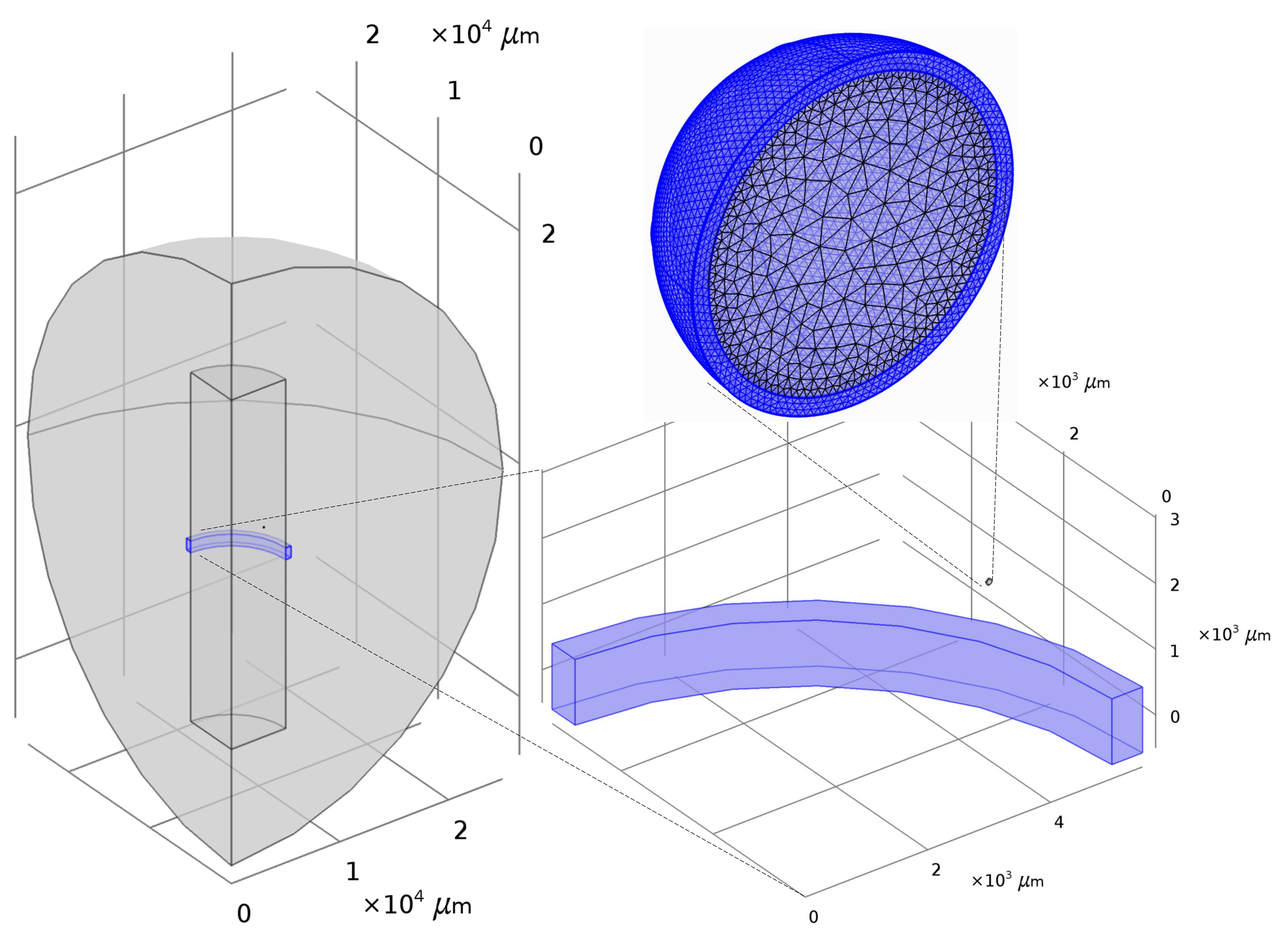

**Figure 2**. Quarter model, zoomed inductor and bead with magnetic coating

**RESULTS**: Utilizing this two step approach it is possible to export the magnetic forces for different inductor currents and windings, bead radii and permeabilities as well as geometrical properties of the system.

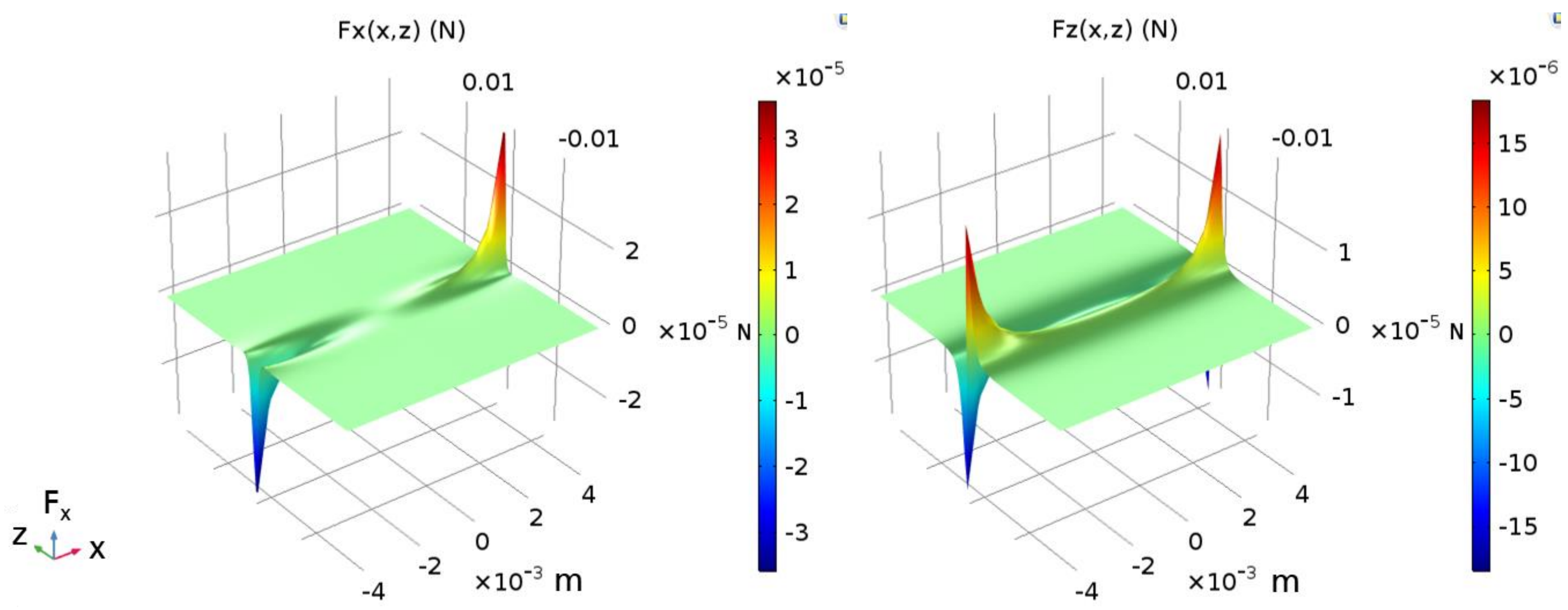


**Figure 3**. Magnetic forces in radial (x) and height (z) direction

The movement of the beads in the viscous medium can be calculated for different bead and medium properties independently from the first step and a lot of simulation time will be saved in this way. In figure 4 the trace of a bead is shown which is initially located at the position x=4mm, z=20mm. The inductor at the height of z=0mm with 1000 windings and 5mm inner radius is driven with a current of 1A. It is easy to see that the bead is moving at first towards the inductor and the center of the system (x=0mm). Close to the inductor location the bead is moving away from the center and finally reaches the inner wall of the disposable where the inductor is located. Furthermore, the timing of the bead movement is very important for the application and can easily be visualized using COMSOL®.

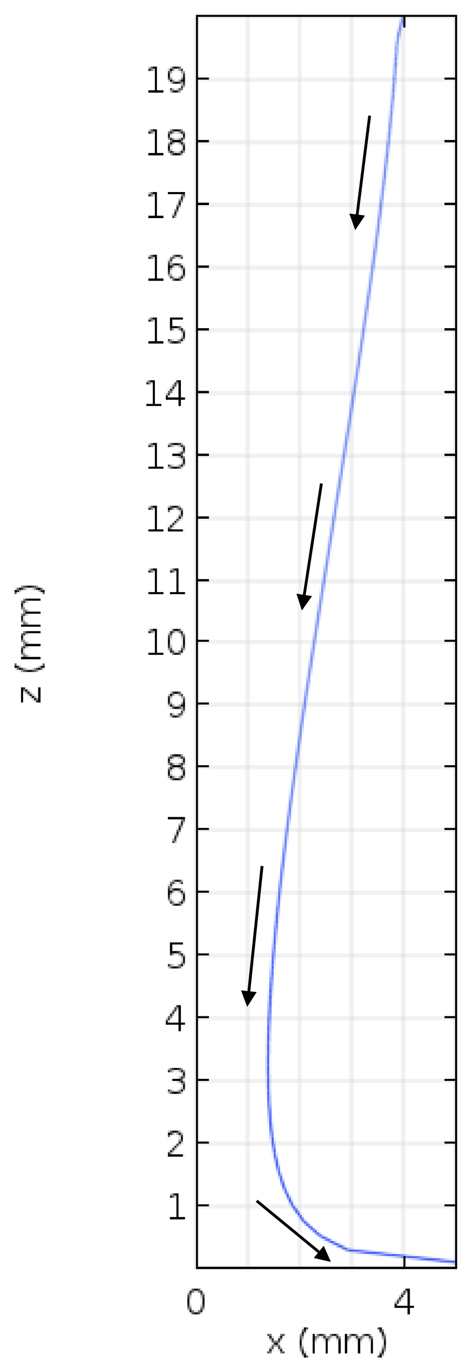


**Figure 4**. Trace of a bead

**CONCLUSIONS**: The feasibility of the concept could be shown. The bead movement was analyzed and depicted without building prototypes in advance and using microscopes to monitor the very small beads. Geometrical, magnetic, and electrical parameters where derived to build up a prototypical system.

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